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<p>(54) Title: PROCEDURE FOR PREPARING SILICA FROM CALCIUM SILICATE</p>			
<p>(57) Abstract</p> <p>This invention concerns a procedure for preparing amorphous silica from calcium silicate and CO₂, with formation and separation of precipitate CaCO₃.</p>			

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"Procedure for preparing silica from calcium silicate."

This invention concerns a procedure for preparing amorphous silica from calcium silicate.

5 From the literature, many methods are known for obtaining amorphous silica from various materials. The starting materials used are generally silicates of alkaline metals, preferably sodium, as described for example in WO96/30301.

10 A particularly interesting starting material is calcium silicate.

Natural or artificial calcium silicates are low-cost materials which, by means of the reaction of CO_2 in water, allow solid mixtures of SiO_2 and CaCO_3 to be 15 obtained, products with a high added value.

However, the use of calcium silicates instead of silicates of alkaline metals, or particularly instead of sodium silicate, presents considerable problems due to the poor solubility of calcium silicate in water, in 20 comparison with sodium silicate.

An example of a procedure for obtaining silica and compounds of silica and calcium carbonate from calcium silicates is described in patent CA 1,122,779. That patent describes a procedure for obtaining silica, in

which the calcium silicate crystals are placed in contact with CO₂ in the presence of water and converted into silica, having the same configuration as crystals of silicate, and into particles of calcium carbonate 5 attached to the particles of amorphous silica. The SiO₂-CaCO₃ mixture is not separable and so, to recover the silica, a treatment with mineral acids is carried out. The acid decomposes the calcium carbonate into CO₂ and calcium salts. The acid may be HCl, for example, thus 10 obtaining CO₂ and calcium chloride. It is then washed with water to eliminate the calcium salt, thus obtaining an aqueous suspension containing silica. However, with a procedure of this type the quantity of silica obtained is extremely low in comparison with the volumes of liquid 15 involved. There is therefore a low production rate per unit volume, which considerably penalises the process described even though it allows particularly pure silica to be obtained.

Moreover this procedure requires the use of an inorganic 20 acid and it is not possible to recover the CaCO₃.

The aim of this invention is therefore to develop a procedure for obtaining amorphous silica from calcium silicate which presents high yield and a high production rate; along with high purity of the product.

A further aim of this invention is to obtain a process with a low degree of environmental pollution, since instead of mineral acids it uses CO₂ alone as the acid agent. A further aim of this invention is to recover 5 precipitate calcium carbonate in mild temperature and pressure conditions.

The aim of this invention is therefore a procedure for preparing amorphous silica comprising the following phases:

- 10 10 a) reaction of a calcium silicate with CO₂ in an aqueous environment with the formation of a suspension 1 of agglomerated particles of SiO₂ and CaCO₃;
- 15 b) treatment of the suspension 1 with a compound of aluminium, boron or zinc or mixtures of the same in a neutral or basic environment, and formation of a solid phase 2 in a solution 3 containing particles of SiO₂ with nanometric dimensions;
- 20 c) separation of the solid phase 2 from the solution 3; and
- d) treatment of the solution 3 according to one of the following methods;
- e) precipitation or drying;
- f) gelation.

In the description and the claims of this invention the

expression "amorphous silica" means non crystalline silica which may be obtained in the form of a gel or in the form of a precipitate.

The reaction of phase a) of the process is carried out in 5 an autoclave at a pressure between 0.3 MPa and 3 MPa and at a temperature between 10°C and 100°C. More particularly the phase a) is carried out at a pressure between 1.0 and 2.5 MPa and at a temperature between 15 and 40°C. Preferably the pressure is equal to 2 MPa and 10 the temperature is equal to 20°C or 30°C.

The pH is a function of the CO₂ pressure and, around a pressure of 2 MPa, it stabilises around the value 5.2. The water/calcium silicate weight ratio may have any value, preferably between 16 and 6.4.

15 In these conditions of temperature, reagent concentration, pressure and pH, the reaction proceeds with the dissolution of the calcium silicate and concludes with the formation of an aqueous suspension 1 of agglomerated particles of SiO₂ and CaCO₃.

20 The simultaneous precipitation of SiO₂ and CaCO₃ could be avoided by carrying out the reaction with low loads of calcium silicate (water/calcium silicate weight ratio greater than 16), obtaining a precipitate composed prevalently of CaCO₃ in the presence of a solution

containing nanometric particles of silica. In this system, however, the quantity of silica in the solution would be too low and therefore not sufficient for an industrial realisation of the process.

5 Even if the load of silica were increased, the concentration of silica in the solution would not exceed 10 kg/m³ (± 4); moreover in these experimental conditions this solution is a metastable phase which tends to gel quickly, preventing the separation of the silica from the 10 precipitated solid composed of CaCO₃.

It is known from the literature that the stabilising of a solution containing amorphous silica in particles is a function of the increase of the pH up to alkaline values ≥ 9.5 or of the reduction of the concentrations of 15 alkaline ions (R.K. Iler, The Chemistry of Silica, 1979). Alkaline pH values may be easily obtained by adding, for example, NaOH, while the problem of reaching higher concentrations of silica in the aqueous phase is more difficult to solve.

20 In order to solve this problem, the procedure according to this invention is characterised by the phase b), that is the reaction of the aqueous suspension 1, coming from the acid dissolution, with a compound of aluminium, boron or zinc or mixtures of the same in a neutral or basic

environment.

The neutral or basic environment ($\text{pH} \geq 7$) is preferably realised using a solution of hydroxides or salts of alkaline metals or alkaline earth metals. In particular, 5 the solution is an aqueous solution of hydroxides of alkaline metals or alkaline earth metals and, even more particularly, the solution is an aqueous solution of sodium hydroxide.

The compound of aluminium, boron or zinc is preferably a 10 salt chosen among aluminates, borates or zincates. In particular, the salt is an alkaline aluminate or an alkaline earth aluminate and, even more preferably, the salt is a sodium aluminate.

The treatment in phase b) is decisive for the development 15 of the entire process, being essential for the separation of silica from carbonate.

This reaction allows the modification of the silica surface and the increase of its concentration in the solution 3 at least up to $50-60 \text{ kg/m}^3$.

20 The solution 3 which forms in phase b) contains particles of silica of with nanometric dimensions defined as "primary particles". In particular the dimensions of the primary particles are between 1 and 100 nanometers.

The third phase c) of the process includes the separation

of the solid phase 2 rich in calcium carbonate from the solution 3 containing silica.

The separation phase c) is carried out by means of any of the known methods for phase separations, preferably it is 5 done by centrifugation; if the separated solid mixture still contains silica aggregated with carbonate, it may be recycled and again subjected to the treatment with aluminate.

The fourth phase d) of the process contemplates treatment 10 of the solution 3 containing silica, according to one of the following methods:

according to the first method, indicated as e), the treatment may be carried out preferably by drying or precipitation, obtaining precipitated silica.

15 Precipitation may come about by means of variation of the chemical-physical parameters, with or without the addition of precipitating agents.

In particular, precipitation may come about with the addition of CO₂, at environment pressure and temperature.

20 Afterwards there is the separation of the phases that formed during the precipitation phase. In particular, this separation may be achieved by means of filtration.

The solid kept back by the filter is washed until a neutral pH (about 7) is reached in the washing waters.

According to the method f), the treatment leads to gelation, followed by evaporation of the liquid phase. The gelation treatment, as known in the art, is achieved by acidification, for example by adding CO₂, at 5 environment temperature, to a pH lower than 7. Depending on the temperature at which evaporation takes place, cryogel, aerogel or xerogel may be obtained.

It is to be noted that the first phase of the process (reaction of calcium silicate with CO₂) and the second 10 phase of the process (treatment with salts containing aluminium, boron or zinc) may also be simultaneous and carried out in the same reactor, adequately checking the pH with suitable buffers.

A further aim of this invention is the use of the 15 amorphous silica obtained with the procedure according to this invention as an additive in mixtures for tyres with low rolling resistance force or as a mineral addition in High Performance Concretes (HPC), such as high or very high strength concrete (preferably more than 100 MPa).

20 The term High Performance Concretes (HPC) identifies a class of cement mixes with characteristics of high mechanical strength (compression strength R_c at 28 days greater than 60 MPa).

An example of HPC is a high-strength concrete known as

DSP (densified with small particles). In this material the microstructure of the cement matrix is densified by adding silica fume. In DSP it is possible to reach R_c at 28 days greater than 100 MPa.

5 In particular, also the compound material composed of the mixture of silica and calcium carbonates, obtained according to the procedure of this invention, may be used directly as an additive in mixtures for tyres or in high-performance concretes, for example in a high-strength 10 concrete (DSP).

Moreover the amorphous silica obtained with the procedure according to this invention may be used in many other sectors; it may be used as a reinforcing load in rubber and other organic polymers, as a pigment partially 15 substituting TiO_2 in the production of paper and coating, as a dimmer in the water paint and varnishes industry, as a thinner in solid formulations, as an anti-blocking agent to prevent adhesion between smooth surfaces, as an anti-binding agent or a catalytic support.

20 The principal advantage of the procedure according to this invention is that of obtaining high-purity amorphous silica by means of a process with a low environmental impact, presenting high production rate and high yield at the same time.

A further advantage of this invention is that of obtaining precipitated calcium carbonate in the form of fine particles.

The starting material may be natural, synthetic, 5 crystalline and amorphous calcium silicates.

The starting material may also be clinker of Portland cement. By clinker of Portland cement is meant a hydraulic material which must be composed of at least two thirds in mass of calcium silicates ($3\text{CaO} \cdot \text{SiO}_2$) and 10 ($2\text{CaO} \cdot \text{SiO}_2$). The remaining part contains aluminium oxide (Al_2O_3), ferric oxide (Fe_2O_3) and other oxides. The CaO/SiO_2 mass ratio must not be less than 2.0. The magnesium oxide (MgO) content must not exceed 5.0% of the mass.

15 Clinker of Portland cement is obtained by the baking, at least as far as sintering, of a precisely established mixture of raw materials (raw meal, paste or suspension) containing CaO , SiO_2 , Al_2O_3 and small quantities of other materials. The raw meal, paste or suspension must be 20 finely ground, closely mixed and therefore be homogeneous. The clinker of Portland cement used as the starting material for the process of this invention is preferably rich in silicates and contains low percentages of the other oxides.

A calcium silicate which can be used as the starting material in the process according to this invention is xonotlite ($\text{Ca}_6\text{Si}_6\text{O}_{17}(\text{OH})_2$) which may be synthesised in hydrothermal conditions according to the following reaction: $\text{CaO}/\text{Ca}(\text{OH})_2 + \text{silica (or sand or quartz)} + \text{H}_2\text{O}$ + minor components (silica fume, bentonite) are made to react in the presence of water vapour at a temperature between 176 and 240°C, at a pressure of 1.4 - 1.5 MPa, for a time of 1 to 24 hours, preferably from 1 to 7 hours, with a molar ratio CaO/SiO_2 between 0.65 and 1 and with a specific surface of the reagents from 18 to 22 m^2 . After cooling, filtration and washing, crystals of xonotlite are obtained.

It is also possible to use as starting material a calcium silicate which may be crystalline or prevalently amorphous. In particular, feeding pure quartz with a diameter < 40 μm , CaO (containing about 7% CaCO_3 , with diameter < 25 μm), silica fume and bentonite in a one-litre stainless steel autoclave, lined, with agitator, and letting it react at a temperature between 195 and 200°C for 24 hours at a pressure of 1.53 MPa, prevalently crystalline calcium silicate is obtained. Instead, using reaction times of 4-7 hours, prevalently amorphous silicates are obtained with a surface area equal to

approximately 100 m²/g.

Another calcium silicate that may be used as a starting material is tobermorite.

The following tables 1 and 2 list some conditions of synthesis of xonotlite (xon-1, xon-2, xon-3) and of amorphous hydrate calcium silicates (CSH-1, CSH-2, CSH-3, CSH-4 and CSH-5) which may be used as starting materials for the procedure according to this invention.

Table 1.

Feed	XON-1	XON-2	XON-3
CaO	55.9%	51.35%	51.3%
SiO ₂	43.9%	48.5%	48.5%
Silica fume	0.2%	0.1%	0.2%
Bentonite	0.05%	0.05%	0.05%
H ₂ O	480%	1200%	1200%
Ca/Si	1.12	0.98	1.00
H ₂ O/dry	4.8	12.00	12.00
Temperature	185 °C	195 °C	200 °C
Pressure	1.1 MPa	1.4 MPa	1.5 MPa
Reaction time	24 h	7 h	4 h
Pressurisation	2.5 h	2.5 h	2.5 h
Depressurisation	6 h	6 h	6 h

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Table 2

Feed	CSH-1	CSH-2	CSH-3	CSH-4	CSH-5
CaO	52.9%	52.9%	48.9%	51.3%	51.3%
SiO ₂	46.8%	46.8%	50.9%	48.5%	48.5%
Silica fume	0.2%	0.2%	0.1%	0.2%	0.2%
Bentonite	0.05%	0.05%	0.05%	0.05%	0.05%
H ₂ O	480%	480%	500%	480%	970%
Ca/Si	1.07	1.07	0.89	1.00	1.00
H ₂ O/dry	4.8	4.8	5.0	4.8	9.7
Temperature	175°C	130°C	197°C	198°C	198°C
Pressure	0.85 MPa	0.3 MPa	1.4 MPa	1.4 MPa	1.4 MPa
Reaction time	7 h	0 h	4 h	2 h	4 h
Pressurisation	2.5 h	1.5 h	2.5 h	2.5 h	2.5 h
Depressurisation	6 h	6 h	6 h	6 h	6 h

5 Figure 1 shows an exemplificative diagram representing a particular embodiment of a system for carrying out the procedure according to this invention.

In the diagram shown in figure 1, 11 indicates the

dissolving reactor, 12 the alumination reactor, 13 the solid-liquid centrifuge, 14 the drier or the precipitation reactor, 15 the washing-drying unit and 16 the mixing unit.

5 According to this diagram, CO₂, xonotlite or calcium silicate and H₂O are loaded at 11 and the dissolution reaction then occurs by acid attack of the silicate; the product obtained arrives at 12 where it is treated with preconstituted solutions of sodium aluminate. At 13
10 there is then the separation by centrifugation of a solid phase and a liquid phase.

The solid phase, coming from 13, which by spectroscopic analysis reveals the presence of carbonates, may be sent by means of the mixer 16 to the alumination reactor 12
15 where it is again treated with sodium aluminate, while the liquid phase is sent to the reactor 14. The dried/precipitated product arrives at the washing-drying unit 15, from which the final product, silica, is obtained.

20 The solid phase, coming from 13, may also be sent back to the dissolution reactor 11.

The characteristics and the advantages of the procedure according to this invention will be better understood from the following detailed and exemplificative

description.

Example 1A

25 g of (pure) Xonotlite coming from hydrothermal synthesis and having a specific surface BET equal to 54 5 m^2/g were suspended in 400 ml of water (volume $\text{H}_2\text{O}/\text{g}$ of xonotlite = 16) and the suspension was kept in agitation in a one-litre stainless steel autoclave. The reactor was pressurised with CO_2 at 2.0 MPa and the temperature kept at 20°C. The dissolution reaction was made to 10 proceed for 1 hour, up to a pH of about 5.2. The autoclave was then depressurised and the suspension obtained was filtered. The solid obtained from filtration was composed of the mixture of silica and precipitated calcium carbonate, with percentages (of the 15 dry product) of respectively 51.4% and 48.6%.

This mixture was treated with an aqueous solution of sodium aluminate, prepared from NaOH in quantity 1 M and Al in quantity 0.01 M, at environment temperature, under agitation, for 2 hours.

20 After centrifugation and drying of the surnatant liquid (at pH = 10), a dry residue was obtained (110°C, 4 hours) which on IR analysis revealed an intense and broad absorption at 1015 cm^{-1} , which may be attributed to silicoaluminate entities. The thermal analysis agrees

with the respective spectrophotometric analysis and revealed a high weight loss (about 2.5%) which may be attributed to the loss of free and bonded water ($T \leq 400^{\circ}\text{C}$). The weight loss at $T > 400^{\circ}\text{C}$ is very low (5-10%) and indicates the presence of a low percentage of carbonate and the transformation of the hydroxides present into oxides.

The trend of the curves is very different, for example, from the one that may be obtained analysing the dry residue of the colloidal phase obtained directly after the acid dissolving attack of the phase a).

After treatment of the $\text{CaCO}_3/\text{SiO}_2$ mixture with a solution of sodium aluminate, the solid obtained from drying of the surnatant liquid presented on spectroscopic analysis some absorption bands characteristic of carbonates.

Once washed in water, the IR analysis allowed it to be revealed that these absorption bands were found in the washing waters and no longer in the solid residue, which was therefore silica with high purity.

The precipitated silica obtained after treatment with sodium aluminate is impure with Na_2CO_3 , which is water-soluble and can therefore be removed with washing.

The characterisation of the precipitated silica obtained is shown in the following table 3.

Table 3: Characterisation of precipitated silica (Example 1A).

5	• Specific surface BET (m ² /g) 63;
10	• pH (5% aqueous solution) 7;
15	• loss at 105°C (%) 4.5%;
20	• loss to fire - 1000°C 11.7%;
25	• Analysis of the calcinated product at 1000°C for 2 hours:
30	- SiO ₂ (%) 96.5;
35	- Al ₂ O ₃ (%) 0.65;
40	- Na ₂ O (%) 1.35;
45	- CaO (%) 1.4;
50	- Fe ₂ O ₃ (%) 0.01

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The specific surface B.E.T. is determined according to the BRUNAUER-EMMET-TELLER method described in the Journal of the American Chemical Society, vol. 60, page 309, February 1938 and according to standard ISO 9277-95.

20 The pH is determined according to standard ISO 787/9 (pH of a 5% suspension in H₂O).

Example 1B

The solid residue coming from centrifugation in the

previous example 1A was again suspended in water and treated with sodium aluminate and afterwards centrifuged and dried. This further treatment with sodium aluminate allowed a further recover of silica, allowing a possible 5 exhaustion of the silica present in the starting mixture. The characterisation of the precipitated calcium carbonate, obtained after three treatments with sodium aluminate, is shown in the following table 4.

Table 4: Characterisation of precipitated CaCO_3 (Example 10 1B).

- Specific surface BET (m^2/g) 9;
- pH (5% aqueous solution) 10;
- loss at 105°C (%) ≤ 2 ;

15 Example 2

A mixture composed of Xonotlite and Tobermorite in weight ratios 70:30 was suspended in water (70 g of mixture in 450 g of water) and the suspension kept in agitation in a one-litre stainless steel autoclave. The reactor was 20 pressurised with CO_2 at 2.0 MPa and the temperature kept at 30°C . The reaction was carried out for 30 minutes, always in agitation, up to a pH of about 5.2. The autoclave was then depressurised and an aqueous solution of sodium aluminate, prepared from NaOH in quantity 3 M

and Al in granules in quantity 0.03 M, was directly added in the reactor. The suspension was kept at environment pressure and temperature, under agitation, for 2 hours.

After that period, the suspension in the reactor is 5 centrifuged. Into the liquid, which has a pH value of 11, separated from the solid phase and kept under agitation, CO₂ is bubbled until a pH of 7.5 is reached.

The solid and liquid are then separated by filtration. The solid kept back by the filter is washed with 10 deionised water (until a pH of 7 is obtained in the washing water). The solid obtained is composed of precipitated silica with high purity and it has the characteristics listed in table 5.

Example 3

15 A mixture composed of Xonotlite and Tobermorite is treated substantially following the description in example 2 up to the stage in which the suspension in the reactor is centrifuged. Into the liquid, separated from the solid phase and kept under agitation, CO₂ is bubbled 20 until a pH of 6.5 is reached. The solution gels and is separated by filtration. The gel solid kept back by the filter is washed with deionised water (until a pH of 7 is obtained in the washing water), then dried and crushed. The specific surface BET of the amorphous silica thus

obtained is 90 m²/g:

Table 5: Characterisation of precipitated silica (Example 2).

5	• Specific surface BET (m ² /g) 160;
10	• pH (5% aqueous solution) 7;
15	• loss at 105°C (%) 4.3;
20	• loss to fire - 1000°C (%) 12;
25	• Analysis of the calcinated product at 1000°C for 2 hours:
30	- SiO ₂ (%) 97;
35	- Al ₂ O ₃ (%) 0.7;
40	- Na ₂ O (%) 1.05;
45	- CaO (%) 1.24;
50	- Fe ₂ O ₃ (%) 0.01

15

The following examples refer to a number of tests of application.

Example 4

Using the precipitated silica obtained in example 1A, DSP 20 concrete having the following composition was prepared:

- Cement CEM I 52.5 (Ultracem R) 642 g;
- Aggregate: spherical quartz (max. diam. = 1200 g; 3.2 mm)

- Precipitated silica (S.S. BET = 63 m²/g) 80 g;
- Super-fluidifying acrylic additive 44 g;
(Superflux 2000 AC)
- Mixing water 149 g;
- Water/binder* ratio 0.25;
- Aggregate/binder ratio 1.66

* binder = cement + precipitated silica

With this mixture three test pieces with dimensions 40x40x160 mm were prepared and were subjected to accelerated curing (24 hours in water at 80°C).

5 The mechanical strength values measured on the test pieces were:

R_c = 119 MPa;

R_f = 18.7 MPa.

Example 5

10 A mixture for tyres was prepared containing precipitated silica from example 2.

The specific surface BET of the silica was 160 m²/g.

The mixture was prepared with 40 parts of silica to every 100 parts of styrene butadiene rubber (SBR) and presents

15 the following characteristics:

Ultimate elongation = 720%;

Ultimate tensile stress = 16 MPa;

Modulus at 500% = 6.5 MPa.

So, as previously indicated and shown, the precipitated silica obtained with the procedure according to this invention may be successfully used in high-performance concretes, such as high or very high strength concretes 5 (DSP) or it may be added to mixtures for tyres with low rolling resistance force.

It was also found that both the solid phase 2 and the solution 3 obtained at the end of phase c) of the procedure according to this invention may be used with 10 excellent results as additives in mixtures for tyres and in high performance concretes (for example high or very high strength concretes).

CLAIMS

1. Procedure for preparing amorphous silica comprising the following phases:
 - a) reaction of a calcium silicate with CO₂ in an aqueous environment with the formation of a suspension 1 of agglomerated particles of SiO₂ and CaCO₃;
 - b) treatment of the suspension 1 with a compound of aluminium, boron or zinc or mixtures of the same in a neutral or basic environment, and formation of a solid phase 2 in a solution 3 containing particles of SiO₂ with nanometric dimensions;
 - c) separation of the solid phase 2 from the solution 3;
 - d) treatment of the solution 3 according to one of the following methods;
 - 15 e) precipitation or drying;
 - f) gelation.
2. Procedure according to claim 1, wherein the reaction of phase a) is carried out in an autoclave at a pressure between 0.3 MPa and 3 MPa and at a temperature between 20 10°C and 100°C.
3. Procedure according to claim 2, wherein the pressure is between 1.0 and 2.5 MPa and the temperature is between 15 and 40°C.
4. Procedure according to claim 3, wherein the pressure

is equal to 2 MPa and the temperature is equal to 20°C or 30°C.

5. Procedure according to claim 1, wherein the compound of aluminium, boron or zinc is a salt chosen among 5 aluminates, borates or zincates.

6. Procedure according to claim 5, wherein the salt is an alkaline aluminate or an alkaline earth aluminate

7. Procedure according to claim 5, wherein the salt is a sodium aluminate

10 8. Procedure according to claim 1, wherein the neutral or basic environment is realised using a solution of hydroxides or salts of alkaline metals or alkaline earth metals.

9. Procedure according to claim 8, wherein the solution 15 is an aqueous solution of hydroxides of alkaline metals or alkaline earth metals.

10. Procedure according to claim 8, wherein the solution is an aqueous solution of sodium hydroxide.

11. Procedure according to claim 1, wherein the particles 20 of silica in the solution 3 have dimensions between 1 and 100 nanometers.

12. Procedure according to claim 1, wherein the separation phase c) is carried out by centrifugation.

13. Procedure according to claim 1, wherein the solid

phase 2 coming from the separation phase c) is recycled so as to be again subjected to treatment with sodium aluminate as in phase b).

14. Procedure according to claim 1, wherein the 5 precipitation treatment e) is carried out with the addition of CO₂, at environment pressure and temperature.

15. Procedure according to claim 14, wherein the phases that formed during the precipitation phase are separated by filtration and the solid kept back by the filter is 10 washed until a neutral pH is reached in the washing waters

16. Procedure according to claim 1, wherein the gelation treatment f) is achieved by acidification, for example by adding CO₂, at environment temperature, to a pH lower 15 than 7, and is followed by the evaporation of the liquid phase.

17. Precipitated silica that can be obtained with the procedure according to one of the claims from 1 to 16, characterised by having purity $\geq 96\%$

20 18. Use of the silica obtained with the procedure according to any one of the claims from 1 to 16 as an additive in mixtures for tyres.

19. Use of the silica obtained with the procedure according to any one of the claims from 1 to 16 as an

additive in High Performance Concretes.

20. Use according to claim 19 in high or very high strength concretes (DSP).

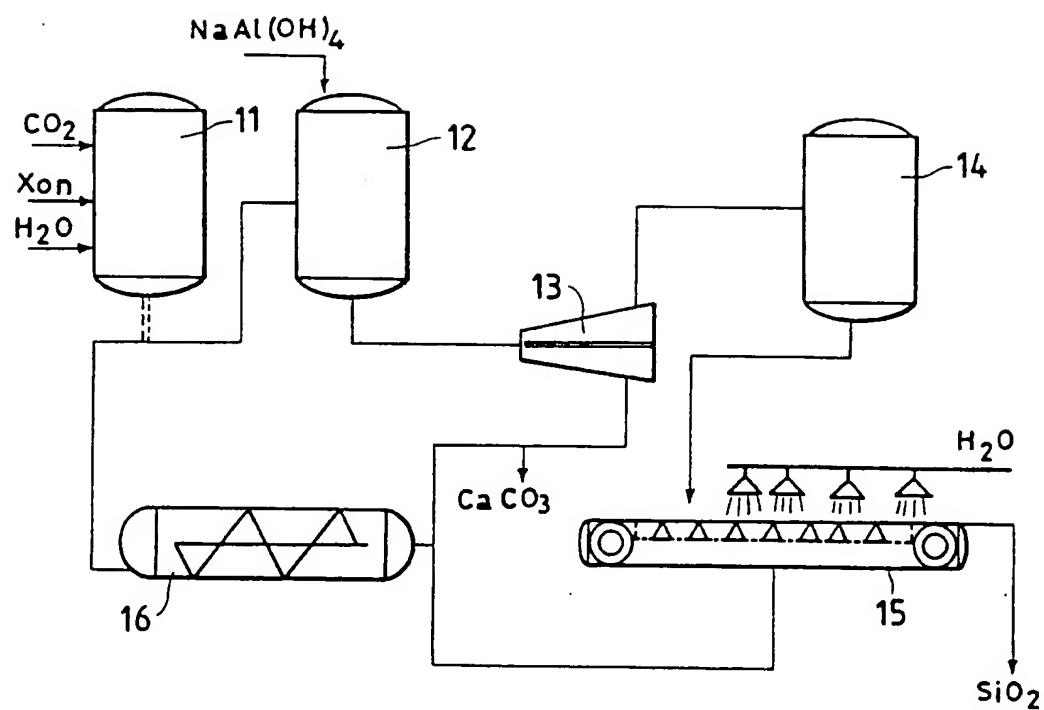
21. Use of the silica obtained with the procedure according to any one of the claims from 1 to 16 as a reinforcing load in rubber and other organic polymers, as a pigment partially substituting TiO_2 in the production of paper and coating, as a dimmer in the water paint and varnishes industry, as a thinner in solid formulations, 10 as an anti-blocking agent to prevent adhesion between smooth surfaces, as an anti-binding agent or a catalytic support.

22. Use of the solid phase 2, composed of silica and calcium carbonate, obtained after phase c) of the 15 procedure according to claim 1, as an additive in mixtures for tyres.

23. Use of the solid phase 2, composed of silica and calcium carbonate, obtained after phase c) of the procedure according to claim 1, as an additive in High 20 Performance Concretes.

24. Use according to claim 23 in high or very high strength concretes (DSP).

25. Composition of precipitated silica which may be obtained according to the procedure of claim 1.

Fig.1

INTERNATIONAL SEARCH REPORT

National Application No
PCT/EP 00/00757A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C01B33/193

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 330 519 A (TAKAHASHI AKIRA ET AL) 18 May 1982 (1982-05-18) column 10, line 4 -column 12, line 60 & CA 1 122 779 A cited in the application ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 548 (C-1005), 18 November 1992 (1992-11-18) & JP 04 209717 A (NIHON INSHIYUREESHIYON KK), 31 July 1992 (1992-07-31) abstract ---	1 -/-

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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16 May 2000

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>DATABASE WPI Section Ch, Week 197748 Derwent Publications Ltd., London, GB; Class L02, AN 1977-85887Y XP002137760 & JP 52 126695 A (OSAKA PACKING SEIZOSHO KK), 24 October 1977 (1977-10-24) abstract</p> <p>-----</p>	1
A	<p>DATABASE WPI Section Ch, Week 197652 Derwent Publications Ltd., London, GB; Class E33, AN 1976-96970X XP002137761 & JP 51 129424 A (OSAKA PACK MFG KK), 11 November 1976 (1976-11-11) abstract</p> <p>-----</p>	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 00/00757

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4330519	A 18-05-1982	JP 1106213 C JP 51125699 A JP 55014809 B JP 1126024 C JP 52008023 A JP 55023788 B JP 1128121 C JP 52008024 A JP 55023789 B AU 502847 B AU 1229376 A CA 1097030 A CA 1122778 A CA 1122779 A CA 1123172 A CA 1122780 A DE 2612281 A FR 2313315 A FR 2332955 A GB 1511125 A IT 1058526 B NL 7603156 A, B, SE 420596 B SE 7603441 A SE 7908472 A US 4230765 A	30-07-1982 02-11-1976 18-04-1980 14-12-1982 21-01-1977 25-06-1980 24-12-1982 21-01-1977 25-06-1980 09-08-1979 13-10-1977 10-03-1981 04-05-1982 04-05-1982 11-05-1982 04-05-1982 20-01-1977 31-12-1976 24-06-1977 17-05-1978 10-05-1982 28-09-1976 19-10-1981 26-09-1976 12-10-1979 28-10-1980
JP 04209717	A 31-07-1992	JP 1982394 C JP 6102533 B	25-10-1995 14-12-1994
JP 52126695	A 24-10-1977	JP 1397069 C JP 61058436 B	24-08-1987 11-12-1986
JP 51129424	A 11-11-1976	JP 1184225 C JP 55023790 B	27-12-1983 25-06-1980

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